

Director's Annual Review
LBNL Physics Division
November 10-11, 2004

Theory Group

- **Overview**
 - who we are
 - how we're organized
- **Research** – a few topics

M. Chanowitz

Staff

LBNL Senior Staff: Barnett (PDG/ATLAS), Cahn (BABAR),
Chanowitz*, Hinchliffe (ATLAS)

LBNL Division Fellow: Ligeti

UCB Faculty: Aganagic (9/04), Bousso (1/04), Gaillard,
Ganor, Hall#, Halpern, Horava, Murayama+,
Nomura (11/03), Suzuki

Retired: Bardakci, Chew, Jackson, Mandelstam,
Stapp, Zumino

Administrative Staff: Kinyanjui, Diaz (60%)

*Group Leader, #CTP Head, +NSF Lead PI

Lab & Campus function as single unified group:

- Postdocs
- Students
- Visitor's program
- Seminars
 - Four weekly group seminars

Monday	Tuesday	Wednesday	Thursday	Friday
4	5	6	7	8
11	12	13	14	15
18	19	20	21	22
25	26	27	28	29
	30	31		

“Strings”
&
“Particle Physics” □ External Speaker
&
Internal speaker

- Fraternization encouraged & practiced

- Starred seminars
- Monthly joint internal meeting

utilizing pooled resources:

- LBNL Physics Division
- UCB NSF theory grants
- Campus-based Center for Theoretical Physics (CTP)
 - UCB endowment (\$1M “seed”)
 - 10 years ops support from LBNL & UCB (~ \$3M)

Postdocs

Gimon	(5 year fellow)	CTP	IAS
Hubeny		CTP	Stanford
Mitra		CTP	Princeton
Pappuci		NSF	Pisa
Perez	(Ligeti OJI)	LBL	Weizmann
Rangamani		CTP	Princeton
Schwartz		NSF	Harvard
Tatar		LBL	Humboldt
Watari	(Miller fellow)	UCB	Tokyo

Many Berkeley postdocs go on to faculty positions.

E.g., 100% of class of 04:

Burdman	U de Sao Paulo
Chacko	U of Arizona
Goldberger	Yale

Students

- Plan to support GSRA's for 2 years, configured as 3 semesters + 3 summers
- Expect to support ~10 starting in 1/05
 - currently supporting 4

Current Roster

D. Chiou (OG)	S. Oliver (LH)
B Feldstein (LH)	C. Park (MKG)
J. Gill (OG)	A. Pasqua (BZ)
R. Harnik (HM)	M. Randsdorp (MKG)
C. Keeler (PH)	P. Shepard (PH)
B. Kim (OG)	B. Tweedie (YN)
D. Larson (HM)	D. Vasilyuk (OG)
A. Mints (RB)	

Visitors Program

Provides support for 1 – 3 week visits

- Intended to foster joint research with group members
- In recent years funded mostly from CTP
- Has proven to be very worthwhile

FY 04 visitors:

K. Agashe	Johns Hopkins	J. McGreevy	Princeton
C. Bauer	Cal Tech	D. Minic	Virginia Tech
O. Bergman	Technion	S. Murthy	Princeton
A. Birkedal	U. Florida	B. Nelson	U. Pennsylvania
C. Burgess	McGill	D. Olive	Swansea (Miller)
C. Csaki	Cornell	E. Poppitz	Toronto
P. Creminelli	Harvard	H. Reall	UCSB KITP
J. deBoer	Amsterdam U.	J. Simon	Penn/Weizmann
C. Grojean	Saclay	W. Skiba	Yale
A. Lewandowski	SLAC	L. Wolfenstein	Carnegie Mellon
M. Luty	U. Maryland		

Outlook

LBNL & UCB both in process of revitalization

LBNL: recovering from defections to expt'l groups

- Ligeti Division Fellow appointment in 2000 first since Cahn & Hinchliffe in 1979 (!)
- Search for new DF currently under way
- Another DF search planned for ~ 07 - 08.

UCB: arrival of three Asst. Profs. in last 12 months

- Mina Aganagic *strings*
- Raphael Bousso *GR/strings*
- Yasunori Nomura *particle physics*

Outlook (2)

Joint UCB/LBNL plan in place to stabilize funding

- joint support for CTP through 2014
from LDRD + Phys Div + UCB
(+ fund raising effort to build endowment)
- Physics Division support for LBNL theory appointments
to offset “defections” to experimental program

Facilities:

- LBNL facilities funds to refurbish lab theory area
- UCB: Major retrofit/renovation of “old Leconte”

In Berkeley campus & lab have had an unusually close & productive relationship, but center of gravity could shift downhill after Leconte renovation.



Important to maintain vitality of LBNL theory,
as the existing plan will do.

Theory Group: broad range of research

E.g.,

- Work closely connected to experiment
 - heavy flavor physics*
 - signals of new physics @ LHC*
 - neutrino mixing +...
- “BSM” model building
 - dark energy from supersymmetry breaking*
 - a Grand Unified Theory that is testable @ LHC
 - extra-dimensional alternative to Higgs mechanism* +...
- String theory
 - possible astrophysical implications of string theory*
 - holographic principle
 - d-branes in background fields & nonlocal field theory +...

* To be discussed in more (though meager) detail by Chanowitz

Some Physics: micro-reviews

- Progress in B physics
- A No-Higgs-mechanism scenario at LHC
- Dark energy from supersymmetry breaking
- Strings and massive black holes

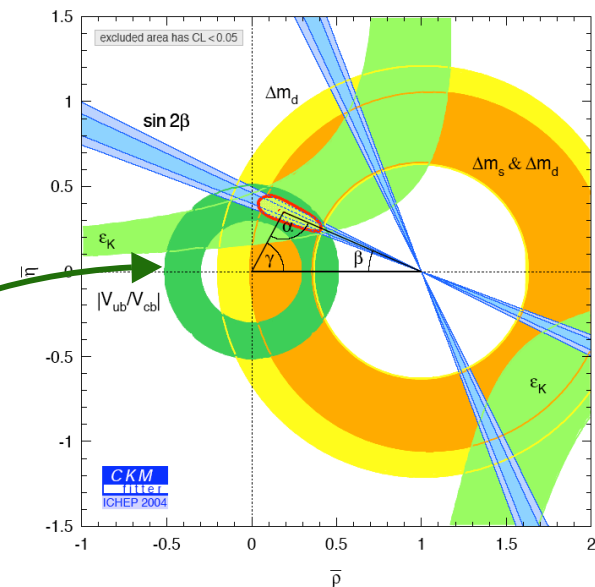
Progress in B physics

Primary goal: measure quark mass matrix
— *especially mixing angles & CP violating phase* —
so we can find the underlying theory.

Not easy: fundamental parameters are obscured by strong interaction physics we don't understand well.

CKM fit (*pre-ICHEP04*) from many measurements, **assuming SM**:

Ligeti: allowing for **New Physics**,
only constraint is **green ring**,
using V_{ub} / V_{cb} from
tree-level B decays.



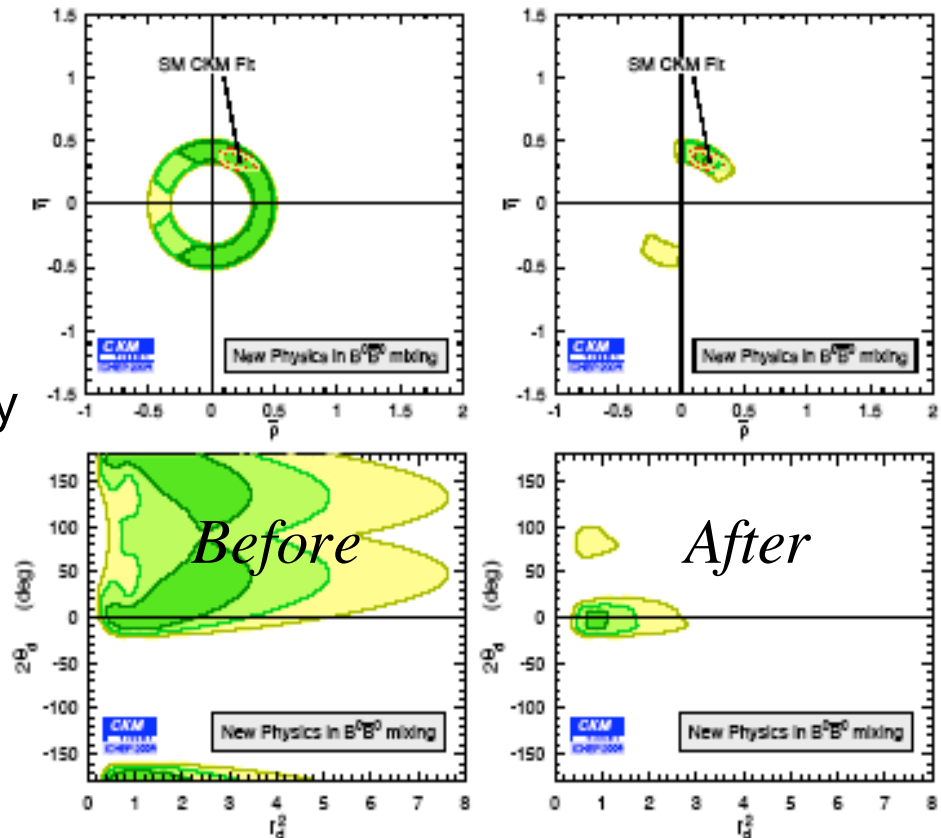
Constraining new physics in B^0 mixing

Ligeti plenary talk at ICHEP04-Beijing,
The CKM matrix and CP Violation.

Of the 3 angles of the unitarity triangle α , β , γ until recently only β was well measured.

Initial α and β measurements imply surprisingly strong constraint on new physics contribution to $B^0 - \bar{B}^0$ mixing, parameterized as

$$M_{12} = M_{12}^{(\text{SM})} r_d^2 e^{2i\theta_d}$$



$r_d^2 - 2\theta_d$ plane

Determining the CKM Matrix

Determination of the CKM matrix is a huge ongoing effort by experimenters and theorists. For theory, as for experiment, careful assessment of the uncertainty is as important as the result. Ligeti *et al.* have made many important contributions, e.g.,

- Determine subleading OPE corrections in same fit with V_{cb} . Find robust central value and error estimate in several theoretical schemes. For perfect experiments, theory error $\sim 1\%$.

hep-ph/
0408002

- **Q:** What difference in $\sin 2\beta$ would signal new physics?

$B \rightarrow \pi' K_S$	0.41 ± 0.11
vs	
$B \rightarrow \pi K_S$	0.73 ± 0.04

PRD68:
015004

A: SU(3) estimate of CKM-subleading contributions gives *conservative* model-independent lower bound, $\beta(\sin 2\beta) > 0.2$

- Strategy for V_{ub} : find cuts on $B \rightarrow \ell \bar{\nu} X$ which minimize theory error — quite different than maximizing acceptance, increasingly relevant as experiments improve.

PRD64:
113004

No Higgs mechanism?

- Higgs *mechanism* an article of faith for 40 years
- Not tested - **LHC will test it**

A specific example of an alternative to the Higgs mechanism has emerged in five-dimensional theories:

- Electroweak sym. breaking by boundary condition on compact 5'th dimension.
- 5-dimensional gauge theory is nonrenormalizable, hence an effective theory up to cutoff scale $\Lambda_5 \sim O(2 - 10) \text{ TeV}$ beyond which the underlying theory will be discovered.
- “Bad” UV behavior cancelled by exchange of Kaluza-Klein gauge bosons, up to scale Λ_5 .

Csaki-Murayama
-Terning ...

Chivukula-
Dicus-He

No-Higgs-mechanism option @ LHC

At LHC, scattering of longitudinal W's ($W_L W_L$) is weak or strong, depending on mass of KK's

$$\begin{aligned} M_1 &\ll 1 \text{ TeV} \\ M_1 &\sim O(\text{TeV}) \end{aligned}$$

weak
strong

As for Higgs mech.,
with $M_1 \rightarrow m_H$

E.g., Toy Model

$SU(2) \times U(1)$

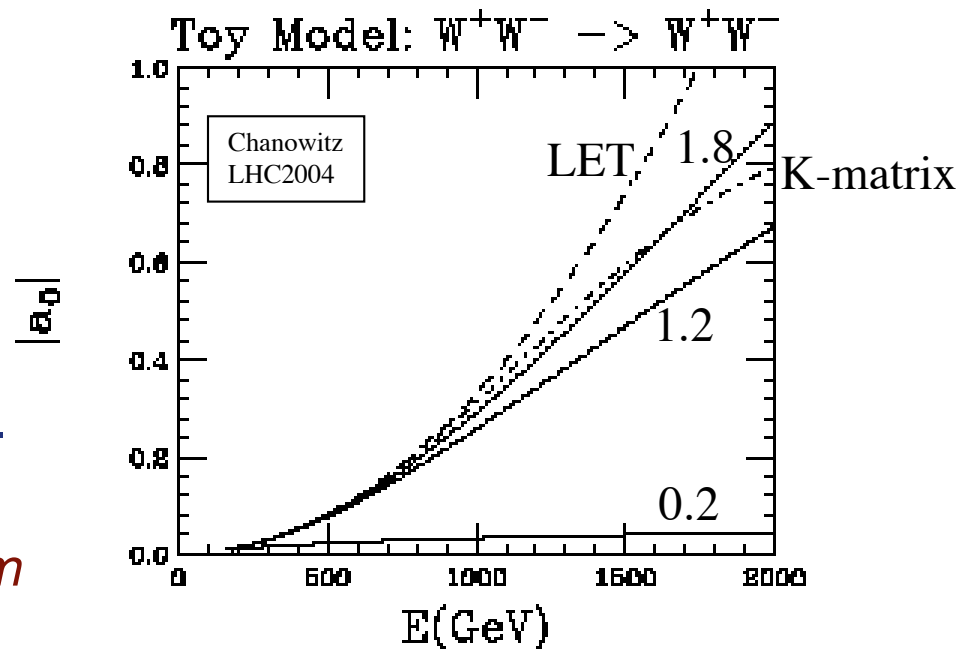
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$$W_L^+ W_L^- \rightarrow W_L^+ W_L^-$$

- Unitarity alla sum rules of Csaki-Murayama et al.
- Consider $M_1 = 0.2, 1.2, 1.8$

For $M_1 > 1 \text{ TeV}$, WW signal @ LHC resembles signal from Higgs mech. with strong dynamics.

Analogous result for *any mechanism* that unitarizes WW scattering:
Weak for $m \ll 1 \text{ TeV}$, Strong for $m \geq 1 \text{ TeV}$



No-Higgs-mechanism: constraints

Strong coupling has smallest EW corrections,
with best chance to agree with precision EW data
(& to evade direct searches for KK states).

Burdman-Nomura

Strongly coupled version resembles technicolor, but with better prospects to include fermion masses without big flavor changing neutral currents.

Higgs gets last laugh?

Leading candidate, AdS_5 , has dual CFT_4 description in which EW symmetry is broken (strongly) by the Higgs mechanism, i.e., technicolor in CFT_4 setting.

Csaki et al.

These models are interesting *per se* but especially as existence proofs that the conventional wisdom does not exhaust all possibilities: **they remind us there could be big surprises at LHC.**

Dark energy from SUSY breaking

Chacko, Hall, Nomura

Dark energy scale $\Lambda_D \sim 10^{-3} \text{ eV} \sim 1 \text{ TeV}^2 / M_{\text{Planck}}$
suggests a “cosmic seesaw”:

Visible sector: SUSY breaking at $O(1 \text{ TeV})$

Hidden sector: SUSY breaking transmitted by gravity
from visible sector

$$\Rightarrow V_{\text{Hidden}} = \Lambda^2 \phi^4 - A(\phi^3 + hc) + m^2 \phi^2 + V_0$$

where $m, A \sim O(\Lambda_D)$

If $A > m$, potential has long-lived metastable vacuum at $\phi = 0$
with $\phi = V_0 \sim \Lambda_D^4$

Eventually there is a 1'st order phase transition to the
global minimum with $V = 0$.

Dark energy/SUSY breaking: signatures

Suppose ϕ interaction with Standard Model gauge fields:

$$\frac{\phi}{M_{\text{Pl}}} \text{Tr} [F^{\mu\nu} F_{\mu\nu}]$$

$$\square \quad V_{\text{grav}} = -(1 + \alpha e^{-r/l}) G_N m_1 m_2 / r$$

$$l \simeq m^{-1}$$

For most of parameter space,

$$\lambda \lesssim 4\pi \quad \square \quad l \gtrsim 24 \mu\text{m}$$

$$\square \text{ perturbative to } M_{\text{Pl}} \quad \square \quad l \gtrsim 110 \mu\text{m} \quad \left\{ \begin{array}{l} \text{Sub-mm} \\ \text{deviations} \\ \text{from Newton} \end{array} \right.$$

Other predictions:

- SUSY particles at LHC
- $w = -1$ except perhaps in recent past
- radiation density \square_\square visible in future CMB experiments

Model #2

Strings & over-rotating Black Holes

Kerr bounds, from classical GR

Work in progress:
Gimon & Horava

$$a = J/M < M$$

$$a^2 + Q^2 < M^2$$

Planck units

from “cosmic censorship”: no naked singularities allowed —
if bound is violated, the horizon vanishes & singularity is exposed.

In 5d SUGRA there are BH’s with $Q = M$ which are resolvable
in string theory, by nonsingular configurations with the same
gravitational potential as the BH beyond the horizon, for arbitrarily
large J , i.e., “over-rotating”.

It’s plausible that similar objects exist in 4d and are similarly resolved
in string theory. After dissipating charge Q they could have $a > M$.
They could be sought in Active Galactic Nuclei or in solar-mass BH’s.

Signature: superluminous AGN's

As particles are accreted by the BH, the percentage η of radiated energy and the last stable orbit r_0 depend on J of the Black Hole:

$J = 0$	$r_0 = 6M$	$\eta = 6\%$	{ Classical upper limit
$a = M$	$r_0 = M$	$\eta = 42\%$	

If over-rotating “BH’s” exist, the efficiency η peaks at

$$a = \sqrt{32/27} M \sim 1.1M \quad r_0 = (2/3)M \quad \eta = 100\%$$

Establishing existence of compact objects with $\eta > 42\%$ would be evidence for physics that resolves the underlying classical BH singularity, as string theory is known to be able to do in some contexts.

Summary

The Theory Group is alive and well
and looking forward to exciting times.